Food value of various stages of *Tetranychus kanzawai* to *Amblyseius womersleyi* (Acari: Phytoseiidae, Tetranychidae)

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ABSTRACT

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Solely offered various stages of the spider mite, *Tetranychus kanzawai* Kishida, adult female phytoseiid mites, *Amblyseius womersleyi* Schicha, consumed more spider mite eggs and larvae, similar numbers of protonymphs, deutonymphs, and adult males, and fewer adult females. Feeding choices revealed that *A. womersleyi* favored eggs and larvae of *T. kanzawai*, had no predilection among *T. kanzawai* nymphal stages and adult males, and tended not to feed on adult females of *T. kanzawai* when there were other prey stages available. Weights of protonymphs, deutonymphs, and adult males of *T. kanzawai* were similar to each other. While feeding on spider mite nymphs, *A. womersleyi* laid significantly fewer eggs than while feeding on other stages of the spider mite. The quantity, in micrograms (μg), of spider mites consumed for each phytoseiid egg laid showed that spider mite eggs and adult females had the highest food value, followed by larvae and adult males, while the 2 nymphal stages had the lowest food value. In order to better estimate the spider mite: phytoseiid ratio for managing spider mite populations, numbers of larvae, protonymphs, deutonymphs, adult males, and adult females of the spider mite were suggested to be unified using spider mite eggs as the standard. As determined by the amount consumed to produce 1 *A. womersleyi* egg, each *T. kanzawai* larva was equivalent to 1.05 eggs, each protonymph to 1.37 eggs, each deutonymph to 1.38 eggs, each adult male to 1.87 eggs, and each adult female to 10.99 eggs.

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(Key words: *Amblyseius womersleyi*, *Tetranychus kanzawai,* stage, food value, feeding choice)

INTRODUCTION

Phytoseiid mites are commonly utilized to suppress spider mite populations, either through augmentation of natural populations or by the release of mass-produced colonies. A certain ratio of predator to prey is generally required to ensure a satisfactory control effect. Field populations of the spider mite and its natural enemies are monitored through an integrated pest management program in accordance with this ratio to decide whether control measures are required. However, spider mite populations composed of the same number of individuals vary in their age structures. A young spider mite population composed mostly of eggs will differ from a more-mature population that contains more nymphs and larvae. This obviously influences the actual rates of predators to spider mites. In order to more-accurately estimate this ratio, the value of each spider mite stage to the predator was studied.

Amblyseius womersleyi Schicha is a phytoseiid mite recorded from the Primorsky area of Russia to New Zealand [7]. It has commonly been collected from *Tetranychus* populations in Taiwan by the author. Releases of *A. womersleyi* in field crops have provided good control of spider mites in Taiwan [1, 4, 7, 12, 13]. Studies have shown that it has a high potential to be a good biological control agent [2, 3, 5-7]. It was therefore chosen together with the most-widely held crop pest spider mite, *Tetranychus kanzawai* Kishida, in Taiwan [8] to compare the food value of the various spider mite stages to its phytoseiid predator.

MATERIALS AND METHODS

Culture Maintenance

Amblyseius womersleyi was obtained from a laboratory culture which the Taiwan Agricultural Research Institute (TARI) has maintained since 1985. *Tetranychus kanzawai* Kishida reared on soybean (*Glycine max* L.) seedlings [10] served as the food source for both cultures.

All studies, except as otherwise described, were carried out in an incubator at 28 ^{o}C with a photoperiod of 13: 11 h (L: D). The response of 2~3-day-old adult female phytoseiid mites was tested, using the leaf-arena method described by Lo and Ho [11].

Consumption of Various Spider Mite Stages

Adult female spider mites were allowed to oviposit for 4 h in the incubator. Eggs were collected and reared to provide various spider mite stages for offering food to the phytoseiid mites. Eighty eggs, 50 larvae, 40 protonymphs, 40 deutonymphs, 35 adult males, or 5 adult females of the spider mite were offered and refreshed daily to each of 10 adult female *A. womersleyi*. The consumption of spider mites by *A. womersleyi* was observed daily for 5 days. An adult female spider mite lays eggs continually, and eggs are more-easily attacked. This affects the consumption of female spider mites by *A. womersleyi*.

Therefore, the test of the consumption of adult female spider mites was conducted at a room temperature of approximately 28 ± 2 ^{o}C, and was examined hourly for 8 h each day, at which time prey eggs produced by the mother prey were removed. The test phytoseiids were then maintained in the incubator until the onset of the next day's observations.

Feeding Choice of Spider Mite Stages

Spider mites at various stages were reared as described above. Ten individuals each of any 2 stages of the spider mite were offered to each of 5 adult female *A. womersleyi*. The prey stages consumed were observed for 8 h.

Weight of Spider Mite Stages

Various stages of *T. kanzawai* were picked out from the laboratory colony, and weighed on a Mettler PM200 electronic balance. The smallest increment on this balance is 0.1 mg.

Data Analysis

Analysis for balanced data (PROC ANOVA, SAS Institute 1988) was used to analyze these data.

RESULTS

Consumption of Various Spider Mite Stages

The amount of prey offered daily was approximately 1.5 - 2 times the amount consumed in primary tests. The numbers of prey killed varied significantly among the spider mite stages offered (Table 1). *Amblyseius womersleyi* killed significantly more spider mite eggs and larvae, and significantly fewer adult female spider mites than other stages. There was no significant difference in the daily feeding rate of *A. womersleyi* on spider mite protonymphs, deutonymphs, and adult males.

Information expressed by the daily fecundity of *A. womersleyi* slightly differed. When fed on spider mite eggs, larvae, and

Table 1. Utilization (mean ± SE) of *Amblyseius womersleyi* on various stages of *Tetranychus kanzawai*

Prey stage	No. of prey consumed daily	No. of eggs produced daily
Egg	46.3 ± 5.3 a[2)]	3.6 ± 0.2 a[2)]
Larva	42.7 ± 1.5 a	3.4 ± 0.2 ab
Protonymph	23.8 ± 0.7 b	2.4 ± 0.2 c
Deutonymph	20.7 ± 1.2 b	2.1 ± 0.1 c
Adult male	21.8 ± 0.5 b	3.1 ± 0.2 b
Adult female[1)]	4.4 ± 0.5 c	3.6 ± 0.2 a

[1)] Observed hourly for 8 h to exclude any eggs deposited, then triplicate determinations were recorded for comparison.

[2)] Data in the same column followed by the same letter do not significantly differ according to the LSD test at the 0.05 level.

adult females, *A. womersleyi* laid significantly more eggs than when fed on spider mite nymphs. According to the daily fecundity of *A. womersleyi*, adult male spider mites were as good a food source as were spider mite larvae, but not as good as spider mite eggs or adult females.

Feeding Choice on Spider Mite Stages

The first prey attacked was, in most cases, the younger stage, which was usually smaller in size. However, when the 2 prey stages were of similar sizes, the younger one might not have been the first attacked. At the end of the 8th h, *A. womersleyi* had always killed a greater number of younger prey (Table 2). The statistical significance of the differences is summarized following.

Eggs	A
Larvae	A
Protonymphs	B
Deutonymphs	B
Adult males	B
Adult females	C

This statistical difference indicates that larvae were as vulnerable as eggs, and the 2 nymphal stages and adult males were equally vulnerable. When presented together with another stage, significantly fewer adult female spider mites were consumed in every

Table 2. Feeding choice of *Amblyseius womersleyi* between every combination of *Tetranychus kanzawai* stages

Prey stage[1)]		No. of prey consumed (mean ± SE)	
A	B	A	B
E	L	2.8 ± 0.4a[2)]	1.6 ± 0.5 a
E	N1	3.2 ± 0.4a	1.2 ± 0.4 b
E	N2	3.6 ± 0.2a	2.2 ± 0.4 b
E	M	4.4 ± 0.5a	2.7 ± 0.6 b
E	F	4.2 ± 0.4a	0.4 ± 0.4 b
L	N1	6.6 ± 0.5a	5.2 ± 0.4 b
L	N2	5.6 ± 0.4a	2.0 ± 0.5 b
L	M	5.8 ± 0.6a	1.4 ± 0.2 b
L	F	6.4 ± 0.7a	0.8 ± 0.4 b
N1	N2	4.6 ± 0.7a	3.0 ± 0.4 a
N1	M	3.6 ± 0.8a	2.0 ± 0.3 a
N1	F	6.4 ± 0.7a	0.6 ± 0.4 b
N2	M	3.4 ± 0.4a	3.2 ± 0.7 a
N2	F	3.8 ± 0.4a	0.4 ± 0.2 b
M	F	3.4 ± 0.5a	1.0 ± 0.4 b

[1)] E, egg; L, larva; N1, protonymph; N2, deutonymph; M, adult male; F, adult female.

[2)] Data in the same line followed by the same letter do not significantly differ according to the LSD test at the 0.05 level.

combination. The chance of been fed upon by *A. womersleyi* was in the order of:

eggs = larvae > protonymphs = deutonymphs = males > females.

Weight of Spider Mite Stages

To compare the quantity of various spider mite stages, the weight of each stage was measured. Due to the small size of the mite, a very large number of mites at each stage had to be collected for weighing. The individual weight of each stage is reported in micrograms (μg), and steadily increased with age (Table 3). Using the egg weight as unity, the ratio of the weight of each stage to the egg weight was calculated as a relative weight. This prominently shows the weight increase among stages.

Based on the daily consumption on each spider mite stage and the daily fecundity of *A. womersleyi*, the quantity, in micrograms (μg), of each spider mite stage consumed daily and that consumed to produce 1 *A. womersleyi* egg were calculated, and results are shown in Table 4. Spider mite eggs and adult females were utilized most efficiently by *A. womersleyi*, followed by larvae and adult males. The 2 nymphal stages were the least-efficient food source for *A. womersleyi* oviposition compared to the other spider mite stages.

Table 3. Weight (μg) of various stages of *Tetranychus kanzawai*

Stage	Individuals measured	Total weight	Individual weight	Relative weight
Egg	1200	1500	1.25	1.0
Larva	1000	2800	2.80	2.2
Protonymph	800	4400	5.50	4.4
Deutonymph	800	5000	6.25	5.0
Adult male	800	4500	5.62	4.5
Adult female	497	9300	18.71	15.0

Table 4. Number and quantity (mean ± SE) of *Tetranychus kanzawai* consumed to produce 1 *Amblyseius womersleyi* egg

Spider mite stage	Individuals consumed/egg	Quantity destroyed daily (μg)	Quantity consumed (μg)/egg produced
Egg	13.8 ± 2.3	57.9 ± 6.6 c	17.3 ± 2.8 c
Larva	13.1 ± 1.0	119.6 ± 4.1 a	36.8 ± 2.7 b
Protonymph	10.1 ± 0.7	130.9 ± 4.1 a	55.5 ± 3.7 a
Deutonymph	10.0 ± 0.7	129.5 ± 7.3 a	62.6 ± 4.4 a
Adult male	7.4 ± 0.6	122.5 ± 2.7 a	41.5 ± 3.4 b
Adult female	1.3 ± 0.1	83.1 ± 8.7 b	23.5 ± 2.4 c

DISCUSSION

Integrated spider mite management programs always require surveys of the ratio of spider mites and phytoseiid mites to determine what control measures should be implemented. The spider mite population is considered to be controlled by phytoseiid mites when the ratio of spider mites to phytoseiid mites does not exceed 20, and thus no control measures are required [(9)]. However, spider mite stages vary greatly in size. Different stages should be interpreted differently, e.g., 100 spider mite eggs differ from 100 nymphs or any other stage, when calculating the ratio of spider mites to phytoseiid mites. What differences are there in the food values of these spider mites stages to phytoseiid mites? Do phytoseiid mites respond differently to different spider mite stages? To answer these questions, the author carried out this study and presents the information learned herein.

In the feeding studies, the younger the stage of *T. kanzawai* supplied, the greater number of spider mite individuals the adult female *A. womersleyi* consumed, which is as expected. The calculated number of individuals of each spider mite stage consumed to produce 1 *A. womersleyi* egg (Table 4) also supports this tendency. For the oviposition studies, similar daily fecundities were expected if each spider mite stage had similar food values to *A. womersleyi*. The significantly different daily fecundities indicated that these spider mite stages had different food values to *A. womersleyi*.

The daily consumption rate of the various *T. kanzawai* stages by *A. womersleyi* can be assembled into 3 groups, eggs and larvae, nymphs and adult males, and adult females, based on the statistical results. To satiate *A. womersleyi*, *T. kanzawai* eggs were as good as larvae, while the 2 nymphal stages and adult males had similar values. These results were also supported by the feeding choice tests, in which the selection of *A. womersleyi* did not significantly differ between eggs and larvae, or among the 2 nymphal stages and adult males of *T. kanzawai*.

However, the number of individuals consumed to produce 1 *A. womersleyi* egg produced different categories of eggs and larvae, nymphs, adult males, and adult females. Which ranking system should we accept to categorize spider mite stages? What information do these categories of spider mites present? Can we consider 1 adult female as having the same value as 10 eggs or larvae or 5 nymphs or adult males just based on the daily numbers of these stages eaten by *A. womersleyi*? The weight of each spider mite stage was measured in order to transform the daily number of consumed individuals of each stage to a daily consumed weight to seek a possible answer.

Individual weights of the various spider mite stages superficially appeared to be differentiated into 4 groups, eggs, larvae, 2 nymphal stages and adult males, and adult females, with the eggs and larvae being separated into 2 groups, a result which differs from those described above which therefore complicates the question. The quantities, in micrograms, of each spider mite stage consumed daily and those consumed to produce 1 *A. womersleyi* egg provide better information. Adult female *A.*

womersleyi consumed similar masses, which did not differ statistically, of *T. kanzawai* regardless of whether larvae, protonymphs, deutonymphs, or adult males were supplied, followed by the mass of adult female spider mites consumed, and the mass of spider mite eggs. As the daily fecundity of *A. womersleyi* varied when fed on the different spider mite stages offered as food, the nutritional value of spider mite stages must have varied other than merely by the quantity consumed daily. Therefore, the spider mite quantity consumed by *A. womersleyi* to lay 1 egg was computed. Spider mite eggs and adult females were the most-efficient food for oviposition by *A. womersleyi*, followed by larvae and adult males. Spider mite nymphs were the least-efficient stages.

Lavish feeding was observed in the feeding studies as abundant food was supplied, and may have had certain influences on the results. Yet, since it occurred in every treatment and might be a normal phenomenon, its influence was disregarded.

Combining the above results, the author proposes to transform the different spider mite stages of field populations into a relative value, when calculating the *T. kanzawai*/*A. womersleyi* ratio for monitoring spider mite populations.

$Value_{stage}$ = $Quantity_{stage}$ consumed (μg) for producing 1 predator egg/Individual $weight_{stage}$ (μg).

This in fact becomes:

$1/number_{stage}$ consumed for producing 1 predator egg.

By unifying this value with the value of the egg stage as unity, the relative value of spider mite eggs was 1.0, of larvae was 1.05, of protonymphs was 1.37, of deutonymphs was 1.38, of adult males was 1.87, and of adult females was, 10.99.

With these relative values, it is possible to make more-accurate calculations of the predator to spider mite ratio for judging the necessity for any control measures. However, more studies need to be carried out, such as more-detailed studies to improve the above equation and studies on the influences of the age structure of phytoseiid populations.

In addition, the above results indicate that the population increase rate of *A. womersleyi* in the field will vary with the food content of adult female mites. At the beginning when spider mites establish a population, the spider mite colony is composed mainly with adult females and eggs, and *A. womersleyi* will lay more eggs. After the density increases, the spider mite population contains more nymphs. The fecundity of *A. womersleyi* would be a little lower at this time. This may partially explain why phytoseiids should be applied at low densities of spider mites.

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摘　　要

何琦琛*　2005　神澤氏葉蟎各齡期對溫氏捕植蟎的食物價值　植保會刊 47：15 – 23　（台中縣霧峰鄉 行政院農業委會農業試驗所應用動物組）

供應神澤氏葉蟎的不同齡期爲食物，溫氏捕植蟎雌成蟎對葉蟎的卵及幼蟎期取食數量多於其他齡期，取食相似數量的前若蟎、後若蟎及雄成蟎，而對雌成蟎取食數最少。取食偏好選擇試驗顯示溫氏捕植蟎雌成蟎喜好取食葉蟎的卵及幼蟎，對若蟎及雄成蟎無選擇偏好；當其他齡期存在時，傾向於捕食其他齡期而不捕食雌成蟎。前若蟎、後若蟎及雄成蟎的重量相近。取食若蟎時溫氏捕植蟎的產卵量顯著低於取食葉蟎的其他齡期時。比較溫氏捕植蟎每產一粒卵所需捕食的葉蟎各齡期的重量，葉蟎卵及雌成蟎的食物價值最高，幼蟎及雄成蟎居次，若蟎期最低。在管理葉蟎族群評估捕植蟎的抑制力時，可以葉蟎的各齡期換算爲以卵爲基準的數值，而獲得對葉蟎：捕植蟎比率較精確的計算。根據溫氏捕植蟎每產一粒卵所需捕食的葉蟎各齡期的量，神澤氏葉蟎的幼蟎、前若蟎、後若蟎、雄成蟎、雌成蟎各相當於 1.05、1.37、1.38、1.87、10.99 粒卵。

(Key words: 溫氏捕植蟎、神澤氏葉蟎、齡期、食物值、取食選擇)

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